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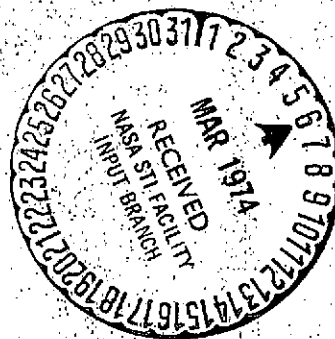
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FOR THE HAND AND DISTAL FOREARM

Sh. Figar

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Among the various kinds of plethysmographic equipment, mechanical plethysmography is still holding its place because of the definite merits which distinguish this old but dependable method of measuring vascular reactions. Numerous discussions have already been presented on the advantages and disadvantages of mechanical plethysmographs and other methods of plethysmographic measurement (electric, photoelectric, etc.). In addition, we have also discussed this in previous works where we described several improvements we introduced into mechanical and electric plethysmography (Figar 1954, 1955a, 1955b, 1956a, 1956b). These descriptions concerned only the main principles and some details could not be listed there. However, in working successfully with mechanical plethysmography these very details are often of decisive importance. In this report we shall, therefore, give a description of a mechanical plethysmograph (for the hand and distal forearm) with several of our own improvements made on equipment we designed. This equipment was built to our specifications by the laboratory mechanic, T. M. Zadrzhil. In our laboratory practice the equipment has already been used for four years and during all that time it has completely demonstrated its value. The equipment has also proven itself in several other medical institutions in Czechoslovakia and the German Democratic Republic where duplicates are being used.

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\*Numbers in the margin indicate pagination of original foreign text.

\*\*Laboratory for Graphic Diagnosis, Czechoslovakian Academy of Sciences, Prague.

## DESCRIPTION OF EQUIPMENT

### 1. Plethysmographic Vessel and its Accessories (Fig. 1)

The plethysmographic vessel is a hollow cylinder (1) with an outside diameter of 100 mm and a length of 250 mm, made out of plexiglass (Umaplex - 3-4 mm thick). The inner bottom of the cylinder is covered with a round umaplex plate 100 mm in diameter and 10 mm thick. The outer bottom of the cylinder is secured in the side wall of the vessel (2). The cylinder continues into a tube which is attached to the side (2) by a flange. There is a round rubber seal between the side and the flange. The outer rim of the tube is reinforced with a small circle with rounded edges to keep the rubber glove from rupturing. The entire tube together with the flange and the reinforcement are made of umaplex. At a distance of 50 mm from the inner bottom of the cylinder (1) the upper part of a tube (9) 35 mm in diameter and 60 mm high opens into the cylinder. In the upper part of the cylinder (1) along its entire length down to the tube there is a wedge forming a gradual rise of the top of the cylinder with maximum at the tube (9). In the inner bottom of the cylinder is attached a brass three-way valve, one tap of which opens into the cylindrical vessel (1), the second into the water level indicator whose upper end is attached to the top of the insulation vessel (4) and opens to the air, while the third tap (7) opens to the insulation vessel. In the lower edge of the inner bottom of the cylinder (1) there is a vent pipe issuing through the wall of the insulation vessel to a one-way brass valve. On the same side is attached a remote one-way brass valve (11). Both these valves are interconnected with the pipe opening to a reserve Marriott jar, not shown in the illustration. Valves (10) and (11) are used /76 to admit and discharge water to the insulation vessel, as well as the plethysmograph cylinder.

To the top of the insulation vessel (4) is attached a brass three-way valve (12) opening through one tap to the pipe (9), through the second to a volume recorder (15) and through the third to the air. This tap is attached to a small rubber tube (14) with a small glass pipe on the end through which the experimenter can, by blowing in or exhausting air, cause reduced or excess pressure in the plethysmographic vessel. These manipulations are necessary in emptying and filling the vessel and in inserting the extremity into the plethysmograph. Symmetrically attached to the lower edge of the bottom of the insulation vessel are two electric

heaters (5) with energy input of 200 W, placed in protective brass tubes fastened to the bottom of the insulation vessel with flanges. A Vertex contact thermometer (6) and a mercury cut-off relay (6) are also attached there with a rubber tube. (The contact thermometer and the relay can also be replaced by a bimetal switch). A rubber surgical glove is put onto the tube which is the external continuation of the plethysmographic vessel; it protrudes freely into the cavity of the plethysmographic vessel (3). It is attached in the tube by a rubber disk (cut out of the thickened edge of a rubber glove). The glove is stretched to one third the size of the forearm (by gluing two gloves together, with the finger part of one cut off). Sealing the extremity to the inlet of the plethysmographic cylinder is accomplished by using one or two conical rubber inserts (13) fitted to the shape of the hand (Fig. 4).

After the extremity is inserted into the plethysmograph and it is sealed at the inlet with rubber inserts, it must be immobilized so that it is not squeezed out of the cylinder by hydrostatic pressure of the water column. To this end a support was made for the elbow. It consists of a bearing rod, a movable clamp with a fastening screw and a semicircular plate covered with foam rubber (glued on) (Fig. 5). For the comfort of the subject a wooden back was constructed, covered with foam rubber.

## 2. Linear Recorder of Volumetric Change (Fig. 2)

The linear recorder [(15) in illustration 1] consists of:

a) a duraluminum drum (1) with an outside diameter of 30 mm and a height of 35 mm, terminating in its lower part in a duraluminum tube with an outside diameter of 10 mm and a length of 25 mm, on which a rubber drive sleeve (not illustrated) is placed. The other end is connected with the tap from the plethysmograph. The upper open edge of the drum is tapered ( $2^\circ$ ) along the inner side;

b) a sealing duraluminum disk (5) tapered ( $2^\circ$ ) on its outer surface;

c) a rubber membrane (2) which is part of a condom (the kind without the reservoir) (3), inserted between the cone of the drum and the sealing disk (5). The membrane is stretched in the opposite direction across the drum so that it forms a bag-shaped curve, as shown in Fig. 2 (4) — detail of the recorder;

d) an umaplex bell-shaped cover (6) with an outside diameter of 36 mm, a height of 45 mm and wall thickness of 0.5 mm; a wire rod is attached to the top point. The drum (1) is secured with a cross clamp to the lower end of a bearing

beam from the duraluminum tube, on the upper end of which a transmitter is attached with a cross clamp. The transmitter consists of:

- a) a support bar to which the block bearing is attached,
- b) a small spiral tightening spring (11),
- c) a bearing for the second tightening block,
- d) a sliding nut,
- e) rollers (7) fastened to axles mounted in both bearings so that their rotation surfaces are mutually perpendicular. Therefore, the vertical movements of the bell-shaped cover are converted to horizontal movements of the recording lever (14). The diameter of the rollers: 14 mm (vertical rotation plane) and 10 mm (horizontal rotation plane).

### 3. Ink Recording Pen (Fig. 2)

The pen consists of a metal socket (9) made of duraluminum foil rolled into a tube with two opposing holes at the end intended for the axle of the pen. The socket is inserted into the open end of a celluloid recording lever which is at the /77 same time an ink reservoir. The pen itself is a small glass tube (8) drawn out to a point and bent at approximately a  $110^\circ$  angle. A wire is soldered on its wide end to be used as an axle inserted in the openings of the sleeve (9). Recordings are made on ordinary paper tape moving on a horizontal plane (15).

### DISCUSSION

In this form the equipment has been very successfully used for a long period of time in laboratory practice.

The plethysmographic vessel itself with its accessories is distinguished by the following qualities:

All servicing is accomplished through only two three-way valves. Placing the gauge glass inside the water bath and connecting it with the plethysmographic cylinder by a three-way valve makes it possible, without any difficulties, to calibrate volumetric changes and note the amount of water admitted during test sessions. Calibration or the admission of a certain amount of water is accomplished so that water is admitted through the three-way valve up to a certain mark on the water level gauge (the three-way valve is in a position to cut off the flow of water from the insulation covering into the plethysmographic cylinder). Then the three-way valve

is regulated to a position allowing water to flow out of the gauge to the plethysmographic cylinder. In calibration a reading is taken of the corresponding deviation in the plethysmographic recording. The water in the plethysmographic cylinder is heated indirectly (by warm water from the insulation cover). The plethysmographic cylinder is designed so that variations in its water temperature are as small as possible. At the start and during test sessions it is often necessary to admit water to the plethysmographic cylinder, either to equalize the water level when the volume of the extremity is reduced more significantly or for other reasons (adjustment, calibration, etc.). Our design makes it possible to admit water directly from the insulation cover. In comparison with other previous solutions to this problem, our unit has the advantage that admitted water is always the same temperature as that surrounding the extremity, as there is no conduit along pipes and, therefore, also no cooling of the water. The extremity being tested is not, therefore, subjected to any undesirable temperature effects during this manipulation. This is very important from the point of view of measuring vascular reactions. The design of the upper part of the plethysmographic cylinder in the form of a gradually increasing vault from the inlet to the inner end of the plethysmographic vessel limits the formation of air bubbles when the plethysmographic vessel is being filled with water. This eliminates the necessity of removing air bubbles by movements of the hand (which, ultimately, affects its circulation), which is already inserted into the apparatus. The hand is placed in the apparatus so that one or two rubber inserts are attached to the extremity (depending on the size of the forearm). The inserts conform to the shape of the forearm. Their conical form permits them to be placed in the inlet and a perfect seal be achieved without simultaneously pressing the extremity. Sealing can be accomplished in several seconds.

This linear recorder of volumetric change can also be used very well (with appropriate selection of dimensions) for pneumographic and pneumotactographic recordings, for plethysmography on animals, finger plethysmography and other kinds of plethysmography, for autographic and tonometric (together with monometer) recordings and in general for linear read-outs of volumetric changes under isotonic conditions. In all these cases our unit completely and with greater success replaces the so-called Marey capsule and other similar units. By using different diameters and ratios of block size and different levers of the transmitting mechanism, we will

achieve various degrees of increase or decrease of deviations of the recording lever. We discussed the principle, merits and maintenance of our read-out and recording unit in more detail in previous works (Figar 1954, 1955a, 1955b, 1956b).

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16. Abstract A description is given of a mechanical hydraulic plethysmograph for the hand and distal forearm with a suitably shaped plethysmographic vessel placed in a water bath, which is at the same time a water supply reservoir with a calibration unit, with practically linear mechanical ink recording and a suitable means of sealing and immobilizing the extremity being tested.			
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